European Heart Journal Advance Access published October 25, 2016

European Heart Journal (2016) **0**, 1–10
doi:10.1093/eurheartj/ehw459

SPECIAL ARTICLE

Mapping cross-border collaboration and communication in cardiovascular research from 1992 to 2012

Diane Gal[1], Wolfgang Glänzel[2], and Karin R. Sipido[3]*

[1]Department of Cardiovascular Sciences, KU Leuven, Leuven 3000, Belgium; [2]ECOOM and Dept. MSI, KU Leuven, 3000, Leuven, Belgium and Library of the Hungarian Academy of Sciences, Dept. Science Policy & Scientometrics, Budapest, Hungary; and [3]Division of Experimental Cardiology, Department of Cardiovascular Sciences, KU Leuven, Campus Gasthuisberg O/N1 704, Herestraat 49, 3000 Leuven, Belgium

Received 17 June 2016; revised 18 August 2016; accepted 13 September 2016

Aims The growing burden of cardiovascular disease requires growth in research and innovation. We examine worldwide participation and citation impact across the cardiovascular research landscape from 1992 to 2012; we investigate cross-fertilization between countries and examine whether cross-border collaboration affects impact.

Methods and Results State-of-the-art bibliometric methods and indicators are used to identify cardiovascular publications from the Web of Science, and to map trends over time in output, citation impact, and collaboration. The publication output in cardiovascular research has grown steadily from 1992 to 2012 with increased participation worldwide. China has the highest growth as relative share. The USA share initially predominated yet has reduced steadily. Over time, the EU-27 supra-national region has increased its participation above the USA, though on average it has not had greater citation impact than the USA. However, a number of European countries, as well as Australia and Canada, have improved their absolute and relative citation impact above that of the USA by 2006–2012. Europe is a hub of cross-fertilization with strengthening collaborations and strong citation links; the UK, Germany, and France remain central in this network. The USA has the highest number of strong citation links with other countries. All countries, but especially smaller, highly collaborative countries, have higher citation impact for their internationally collaborative research when compared with their domestic publications.

Conclusion Participation in cardiovascular research is growing but growth and impact show wide variability between countries. Cross-border collaboration is increasing, in particular within the EU, and is associated with greater citation impact.

Keywords Cardiovascular diseases • Bibliometrics • International collaboration • Citation impact • Networks

Introduction

In most European countries and the USA, life expectancy has increased significantly, nevertheless cardiovascular morbidity is growing as the population ages. Therefore, despite decreased acute mortality rates, CVD presents a high burden of disease.[1,2] In addition, in most low and middle income countries, the overall burden of CVD, both morbidity and mortality, is higher than in high income countries.[3] This growing burden of disease calls for growth in research and innovation.

To support innovation and address new and unmet needs, the value of cross-border collaboration and networking is well recognized. In Europe, collaborative research is stimulated through EU framework programs.[4] The US NIH has also developed new programs for larger multi-centre research projects.[5] Trans-national research projects are supported through specific programs, such as the

* Corresponding author. Tel: +32-16-330815, Fax: +32-16-330699, E-mail: Karin.Sipido@kuleuven.be

Fondation Leducq,[6] but are usually built around investigator initiatives with most funding allocated at the national level by governments, private, and charitable organizations.[7–10]

Currently objective analysis of research collaboration in cardiovascular research is limited. Therefore, in the present meta-research study we examine how cardiovascular research networks, communications, and interconnections have been evolving over time and whether there is a trend towards more collaborative work. The breadth of published cardiovascular research is a rich source of information for identifying patterns and building understanding. Using bibliometric tools we map trends in publication output and flow of communication at the macro-level from 1992 to 2012 focusing on the cross-border and country-level perspective.

The objectives are (i) to assess country participation and citation impact across the cardiovascular research landscape, (ii) to examine cross-fertilization of cardiovascular research through cross-border collaboration, as well as, flow of communication, and (iii) to explore how international collaboration affects citation impact.

Methods

Full details of the methods can be found in the Supplementary material online, *File S1*.

Data sources

The dataset includes the reference, abstract, address, and citation data for 766 509 cardiovascular publications, established as described in Supplementary material online. Data were obtained from Thomson Reuters (TR) Web of Science Core Collection (WoS) through a custom data license held by ECOOM, KU Leuven; other sources were considered but WoS was the most appropriate (see Supplementary material online). All indicators were calculated and compared using three 7-year time periods: 1992–1998, 1999–2005, and 2006–2012.

Global output and country participation

The most active countries were selected, defined as the countries that contributed to at least 1% of all publications in 2006–2012. Publications were assigned to countries according to author addresses. Each unique country contribution per publication was counted in full, unless otherwise stated. The number and share of publications per country were compared.

Impact

All publications in the Web of Science that cited the cardiovascular dataset were used to calculate a 3 year citation window (citations in the publication year and two following years, i.e. including 2013 and 2014), used in all indicators of impact.

Country-level citations were compared over time, using six indicators[11]: the Mean Observed Citation Rate (MOCR, i.e. the average number of citations per publication per year); the Normalised Mean Citation Rate (NMCR, i.e. the MOCR normalised to the Field Expected Citation Rate, FECR); the Mean Expected Citation Rate (MECR, i.e. the citation rate expected for the journal in which the paper was published); the share of uncited publications, as well as the share of publications cited higher than average across three top citation classes, as previously described.[12]

Collaboration

Publications were defined as domestic publications when author addresses included only one country and as internationally collaborative publications when more than one country was listed. The shares of domestic and international publications per country and time period were calculated.

The strength of collaboration was measured by the number of co-publications between two countries, normalised by the number of total publications for each country, using Salton's cosine equation.[13]

Flow of communication

Citation domesticity and reference domesticity[14] were calculated for each country. Citation domesticity represents the citations received by own country as a percentage of all citations received. Reference domesticity represents the references to own country in (own) publications as a percentage of all references (in same publications).

The standardized flow of citations[15] between individual countries was measured based on the number of citations from CountryA to CountryB, normalised by the total number of references in publications by CountryA and the total number of citations received by CountryB.

Impact of international collaboration

The indicators of impact (above) were used to compare the impact of domestic and internationally collaborative publications by country in 2006–2012.

Software and visualizations

All calculations of indicators were undertaken in Oracle SQL Developer version 4.0.1 and RStudio[16] version0.99.489.

Results

Global output and country participation

The global publication output of cardiovascular research has increased over time with 45% of the dataset being published in the third time window, i.e. from 2006 to 2012. The most active countries between 2006 and 2012, i.e. contributing >1% of the data, are shown in Supplementary material online, *Figure S1B*. These countries contributed to 95% of all publications in the full cardiovascular dataset. Further analysis presents the data of these countries against the background of the entire dataset.

Over the 21 year period, all included countries saw an increase in the number of publications (see Supplementary material online, *Table S2A*). As a supra-national region, the EU-27 countries together produce the highest share of publications—surpassing the USA in both number and share of publications in 1998 (*Figure 1*). However, the most prominent increase in share by time period is for the People's Republic of China (CHN); also ranking 2nd after the USA in 2012, as the most productive country with the highest number and share of cardiovascular publications in 2012 (*Figure 1*). In 1992, there were only 66 cardiovascular publications from China in Web of Science, which climbed to over 4500 publications in 2012. Also notable is that

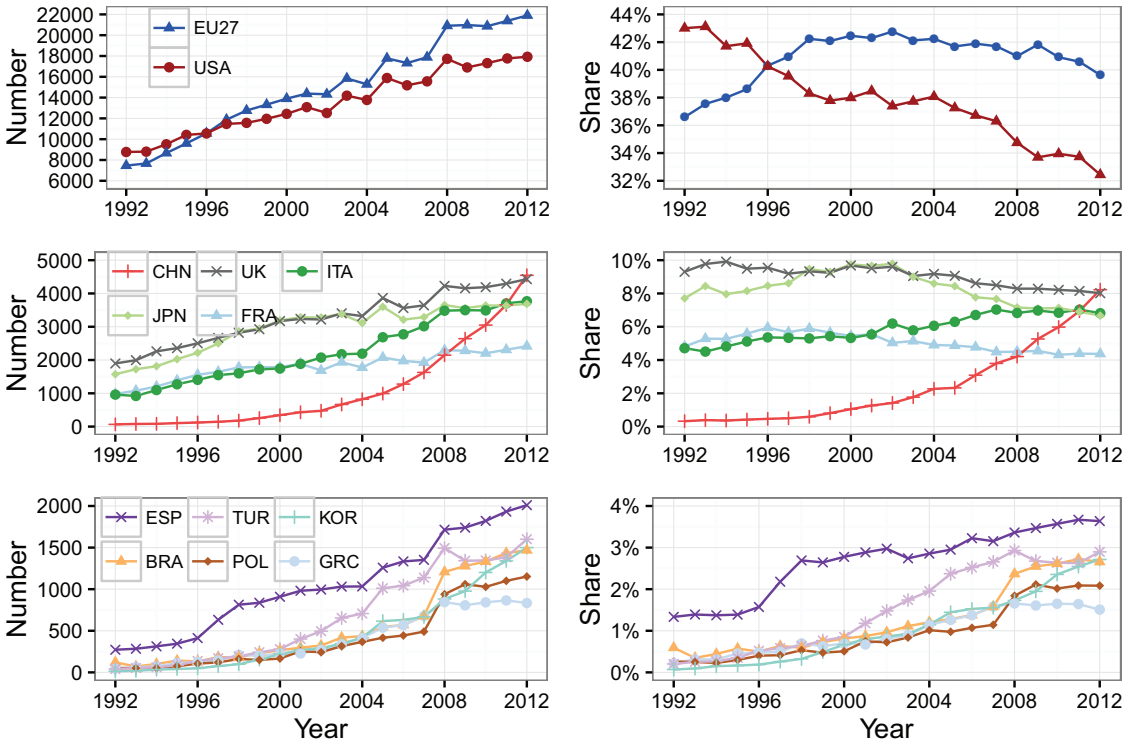

Figure 1 Growth of publication output by country. Number (left) and share (right) of publications presented for countries that experienced greater than 1% change in share of publications between 1992–1998 and 2006–2012. (Data sourced from Thomson Reuters Web of Science Core Collection.)

Italy was the 5th most active country in 2012, publishing a lower share than the UK and Germany but higher share than Japan. In addition, six other countries emerge as having increased their participation and share of publications including: Spain, Turkey, South Korea, Brazil, Poland, and Greece (*Figure 1*).

Country impact

Citations provide a useful indicator of the visibility, use of information and impact of a publication in the global research community. In terms of the MOCR, the average number of citations per publication per year, all countries improved their MOCR between the first and most recent time periods (see Supplementary material online, *Table S2A*).

Twelve countries stand out in their improvement in average and relative citations over time (*Figure 2*, note that countries with no change in average and relative impact are not included). Notably, Denmark and Belgium experienced the most striking increases in average and relative citations over the 21 year period, rising above the USA (NMCR = 1.4) after 1998. Nevertheless, these countries have increased their relative impact over time without substantially increasing their relative participation over time (*Figure 1*).

The rise in NMCR in 2006–2012 for Denmark and Belgium is related, in part, to having a higher proportion of publications cited above average (*Figure 3*). Most notably, the leading position of the USA is challenged over time. In the last time period, The Netherlands, Denmark, and Belgium have greater shares of publications cited above average than the USA, especially in the shares of remarkably and outstandingly cited publications. The rise in impact of Denmark, the Netherlands, and Belgium is also supported by the fact that they have low shares of uncited publications in 2006–2012 (10, 11, and 15%, respectively, vs. 13% uncited for the USA, Supplementary material online, *Table S2A*).

China made the largest improvements with a 13% increase in the total share of publications being cited higher than average over time and also with only 17% of its 2006–2012 publications being uncited compared with 45% in 1992–1998. In contrast, Russia remains the country with the lowest shares of publications cited above average and highest proportion of uncited papers, with only 6% of publications being cited higher than average and 74% of publications being uncited in 2006–2012.

Country collaboration

Over time, there has been an increase in internationally co-authored publications, evidenced by the increased share of multiple country co-authored publications and subsequent decrease in single country authorship of publications (*Table 1*).

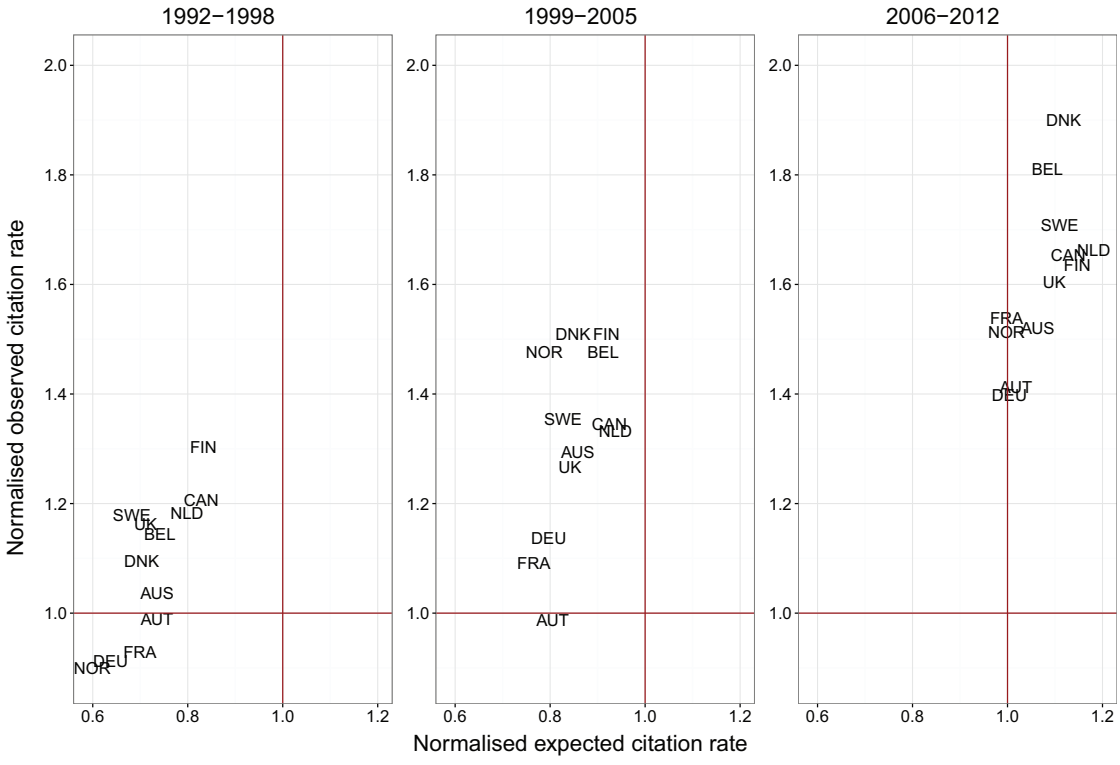

Figure 2 Citation impact evolution. Average citations normalised by the field and journal impact, by country over time. Countries above the horizontal line ($y = 1$) have higher observed impact than all cardiovascular publications in that time period. Countries to the right of the vertical line ($x = 1$) are publishing in journals that have a higher impact than all cardiovascular publications in that time period. Countries presented are those that experienced a greater than average increase in Mean Observed Citation Rate (MOCR change > 3) and an increase to an Normalised Mean Citation Rate or Mean Expected Citation Rate/FECR above 1, between 1992–1998 and 2006–2012. (Data sourced from Thomson Reuters Web of Science Core Collection.)

However, there is substantial variation in the shares of internationally collaborative publications per country; in 2006–2012 the share of internationally collaborative publications ranges from 61% for Switzerland (CHE) to only 9% for Turkey (TUR) (*Figure 4*). To note, 13 countries see an increase of greater than 20% in their share of international publications between 1992–1998 and 2006–2012. While most countries have increased their share of internationally collaborative publications over time, six countries (China, Poland, Brazil, South Korea, Russia, and Turkey) have had a decreased or steady share of international publications over time.

We next examined the strength of collaboration between individual countries. Overall 18 countries have notably strong collaborations with at least one other country during the 21-year period (*Figure 5*). The UK, and then the USA and France had the greatest number of strong collaborations with other countries, with their strength of collaboration increasing over time. To note, the strongest collaborations in 2006–2012 (Strength > 0.09) all exist between close neighbouring countries (see Supplementary material online, *Table S2B*).

Flow of communication

The use of cardiovascular research was analysed by first examining individual countries self-citations and self-referencing behaviours. *Figure 6* (left panel) illustrates the share of citations received, by the cardiovascular dataset, from authors from the same country (country self-citation). Whereas, *Figure 6* (right panel) illustrates the share of references, in the cardiovascular dataset, that have authors from the same country as the citing country (country self-referencing). The USA and Japan are the countries that were cited by and that referenced the highest proportion of their own work, however, the shares decreased over time. In addition, both countries reference their country authors to a greater extent than the citations they receive. Although not presented in *Figure 6*, the EU-27 supra-national region also has high self-citation and self-referencing shares (51 and 47%, respectively in 2006–2012). Although EU-27 reference domesticity has decreased over time, citation domesticity has increased and is higher than the USA in 2006–2012. In contrast, Russia has the lowest citation and reference domesticity, with a decrease in citation domesticity over time. To note, China has relatively low domesticity in 1992–1998, however China has made the largest increases in citation and reference domesticity over time. China's share of country self-citations is also notably higher than the country self-references in 2006–2012.

We next examined how individual countries cite other countries. *Figure 7* illustrates the citation strength as a flow of information from

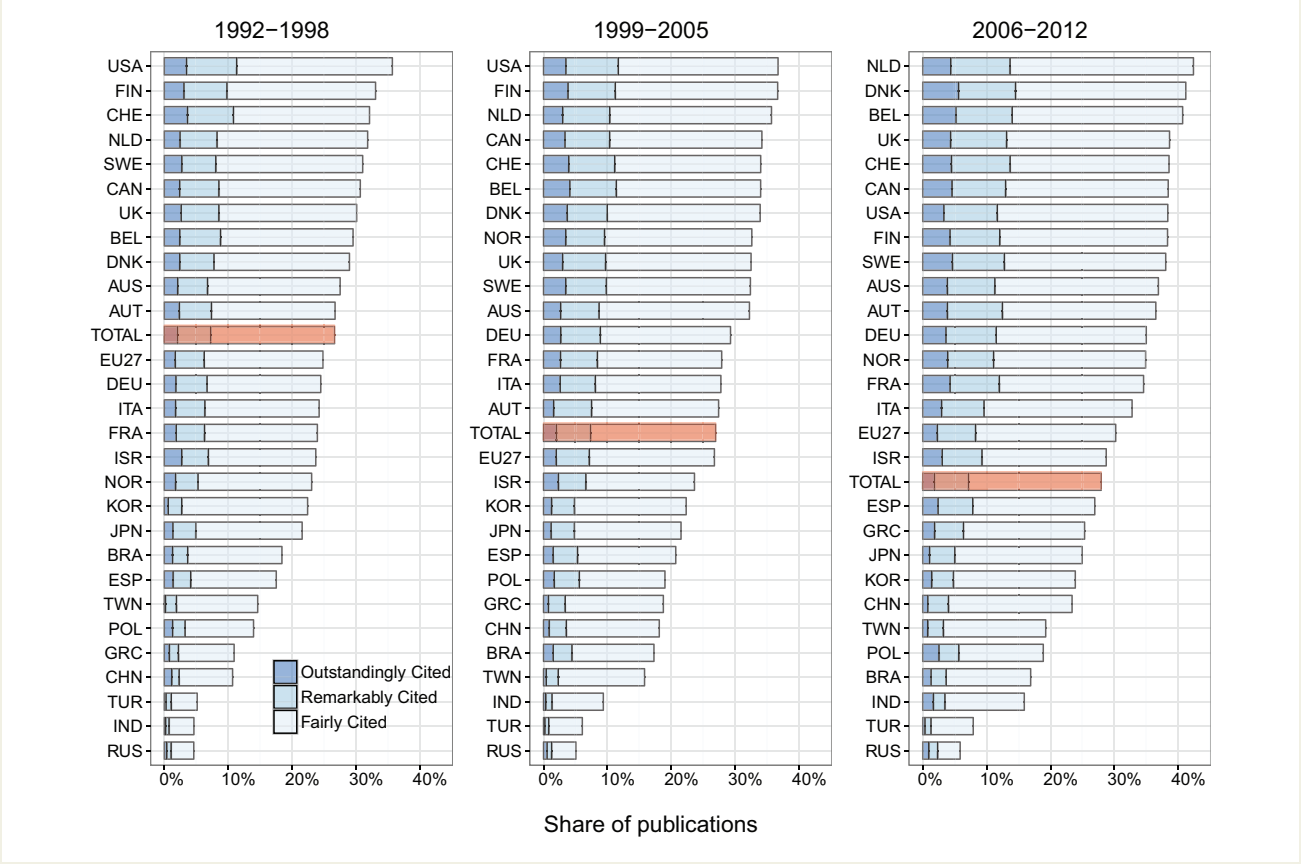

Figure 3 Publications with high impact. Publications cited above average by citation class, time period and country. The combined total of the bars represent the share of publications, for each country, that are cited above average compared with all cardiovascular publications in that time period. The total share of all cardiovascular publications (world standard) that are cited above average for all countries combined is indicated by the red bar. (Data sourced from Thomson Reuters Web of Science Core Collection.)

Table 1 Distribution of publications by number of unique country authors (Data sourced from Thomson Reuters Web of Science Core Collection.)

Authors from	1992	2012
Single country	85%	60%
Two countries	12%	23%
Three countries	2%	7%
More than three countries	1%	10%
More than ten countries	1 publication	45 publications

the country being cited to the citing country. Please note that data are divided, with the left panel presenting the citations to and from the USA, and the right panel presenting data for the UK, Germany and the Netherlands and Italy combined. Full data are available in Supplementary material online, *Table S2C*. The USA is the country that has the greatest number of normalised strong citation links, both in terms of citing other countries and being cited by other countries, with twice as many strong links as the UK. The strongest citation links were countries' self-citations (not shown in *Figure 7*). Between countries, the strongest citation links (Strength > 0.09) were citations between the USA and Germany, the UK, Canada.

Impact of international collaboration

For all countries in 2006–2012, the MOCR per publication, the field normalised citation rate (NMCR) and the MECR of a countries' internationally collaborative publications were higher than for their domestic publications (see Supplementary material online, *Table S2D*).

In addition the international publications for all countries obtained an average citation rate higher than the citation rate for the cardiovascular field (MOCR > 7.3) (*Figure 8A*). Also, all countries except for Turkey, Russia, Greece, and Brazil published their internationally collaborative research in journals that had a higher expected citation rate than the field (MECR > 7.3). We next examined whether the relative citation rates of internationally collaborative publications differ based on the country's level of international collaboration. Overall, the countries with the highest levels of collaboration (share- > 35%) had the highest of both relative citation rates (*Figure 8A*, top). The countries with lower levels of collaboration (share < 25%) tended to have lower relative citation rates. However, for the countries with lower levels of collaboration, Russia's research obtained twice as many citations on average as the cardiovascular field

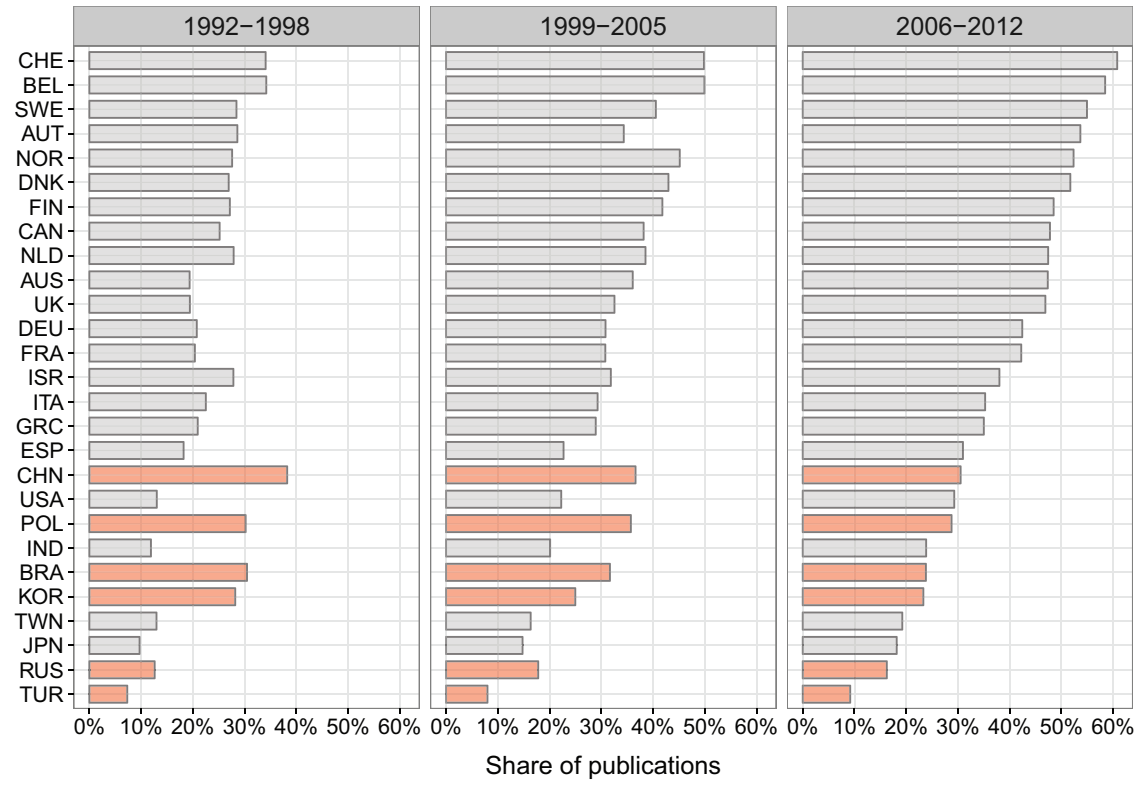

Figure 4 Internationally collaborative publications. Countries with an increase in share of international publications over time are coloured in grey. Countries with a decrease or steady share are in red. (Data sourced from Thomson Reuters Web of Science Core Collection.)

(MOCR > 14.6), while Japan and Korea published their research in relatively high impact journals. Countries with 25–35% share of international publications had varied impact.

Next we investigated how the 2006–2012 shares of internationally collaborative publications compared with the shares of domestic publications in the top citation classes. For all countries and all top citation classes, there were higher shares of internationally collaborative publications than domestic publications (*Figure 8B* and Supplementary material online, *Figure S1C*). In addition, for all countries, the share of internationally collaborative publications that were uncited is notably lower than the share of domestic publications that were uncited (see Supplementary material online, *Figure S1C*).

Discussion

Growth of participation, collaboration and impact

The cardiovascular field overall has seen a growth in output from 1992 to 2012 with increased participation worldwide. A number of countries have seen more growth, others stagnation or even reduction of their share.

The USA and the EU-27 supra-national region have seen substantial growth and over time the EU-27 supra-national region increased its participation above the USA. Although, on average, growth in the EU-27 output has not been matched with greater impact than the USA, a number of small European countries have improved their absolute and relative impact above the level of the USA. Europe is also a thriving hub of cross-fertilization of cardiovascular research through both strengthening collaborations and strong citation links between several European countries, with the UK, Germany, and France remaining central cross-fertilizers in Europe. It has been observed that smaller countries have lower domesticity due to their need to collaborate or network more externally when compared with larger or more geographically isolated countries.[14] The location and size of European countries thus likely contribute to increased collaboration and cardiovascular research in the UK, Germany, and France also have strong national funding as indicated by a recent survey.[7] The present data suggest that this high level of collaboration has contributed to increased impact. All countries, especially smaller, highly collaborative countries such as Denmark, Finland, and Belgium, obtain a higher impact for their internationally collaborative research when compared with their domestic publications across several indicators.

Despite being surpassed by some countries, the USA retains a dominant position in volume of publications and citations. Impact remains high but is not growing. The relative lack of growth may be due in part to the global trend of increasing shares and visibility of publications added to Web of Science from other country authors.[17] The high domesticity in terms of low share of collaboration, and high self-referencing, and self-citations is expected for the USA as a large

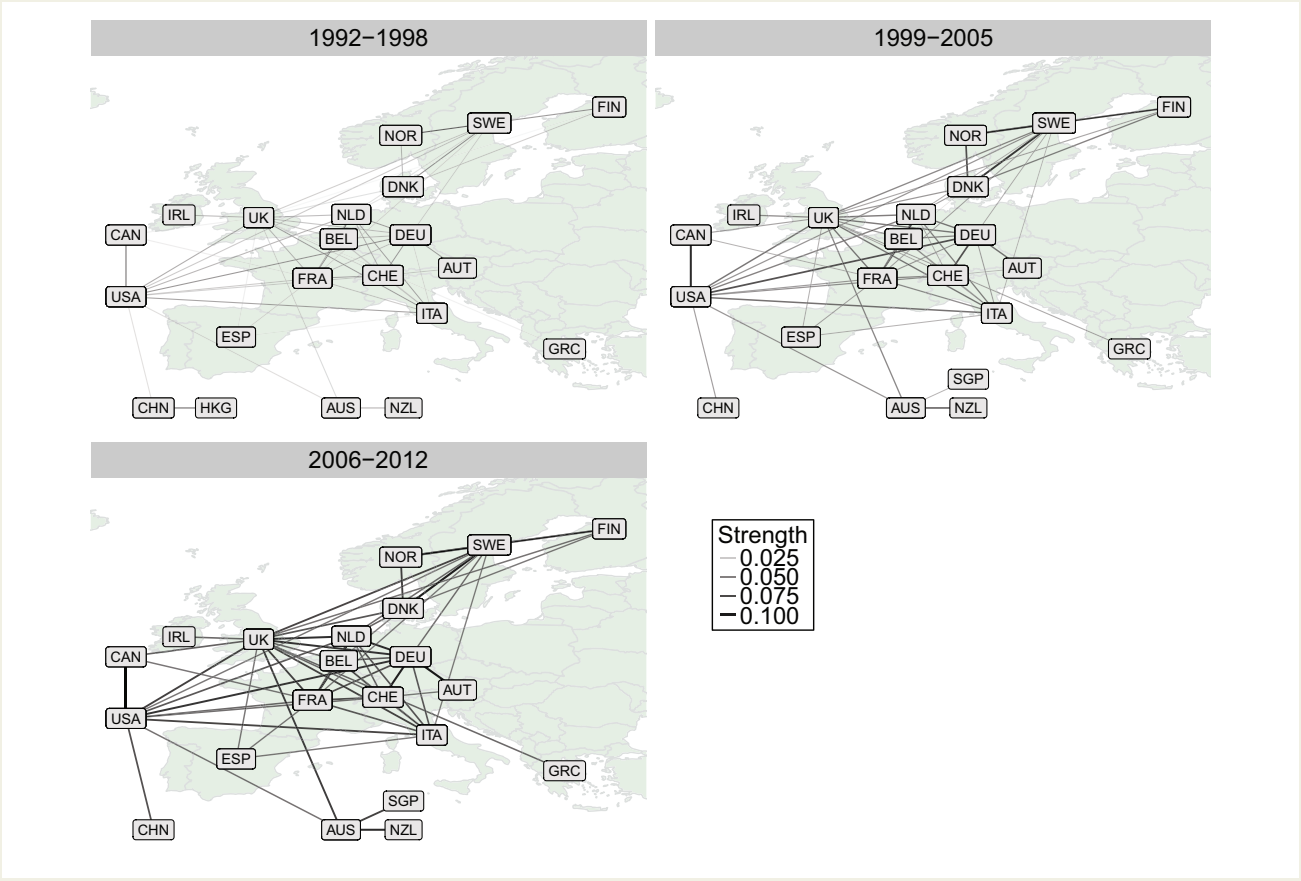

Figure 5 Strength of collaborations between countries. The increased width and colour of the line represent stronger collaboration (see Methods). Only strong collaborations are presented, i.e. where the strength of collaboration was at least 0.05 in one time period between country pairs. (Data sourced from Thomson Reuters Web of Science Core Collection.)

country. Nevertheless, the degree of domesticity is decreasing over time, a sign of increasing international cross-fertilization, through strong flows of citations and the key position of the USA as a strong collaborator with the most active countries. The USA's collaborative publications also have a higher impact than the USA's domestic publications overall.

When considering change over time, China is highlighted as having the largest growth in participation, taking off strongly after 2002. This growth parallels the economic growth and investment in research, especially in recent years.[9,18] With only one strong collaboration with the USA, China has decreased its relative level of international collaboration and increased its reference and citation domesticity over time. As a large country, these findings suggest that China is focusing on increasing its domestic cardiovascular research productivity and citation links. Although its impact is improving, China's growing domestic and international research have not yet achieved the same visibility from the international community.

Japan is one of the few countries that sees a decrease in its share of output, though maintaining quality in terms of impact. It is also one of the countries with high levels of domesticity, indicating that its cardiovascular research remains relatively isolated from the international community.

The consistently low results for Russia are not in line with the size of the country but may reflect the relatively low activity and visibility of Russian cardiovascular research in the international community. That being said, the small share of Russian internationally collaborative publications obtained, on average, twice as many citations as the expected citations for the field in 2006–2012.

Comparison to previously published bibliometric data on cardiovascular research

In preparing this bibliometric study, we undertook a comprehensive review of published bibliometric findings on cardiovascular research (see Supplementary material online, *File S1*). In comparison to this study, most publications included a more limited dataset—of shorter duration, of limited document types, and of limited topic coverage (e.g. only congenital heart disease), that limit the possibility to compare results between the studies. However, a few studies to note include the work by Bolaños-Pizarro *et al.*[19] that focused on cardiovascular research in Spain within the international context from the year 2000 to 2008 and that showed similar trends with our study in terms of participation, impact, and collaboration indicators presented. In addition, two studies based on a broad set of cardiovascular publications from 1999–2008[20] and a subset of publications in eight journals,[21] investigated differences between high, middle, and low income

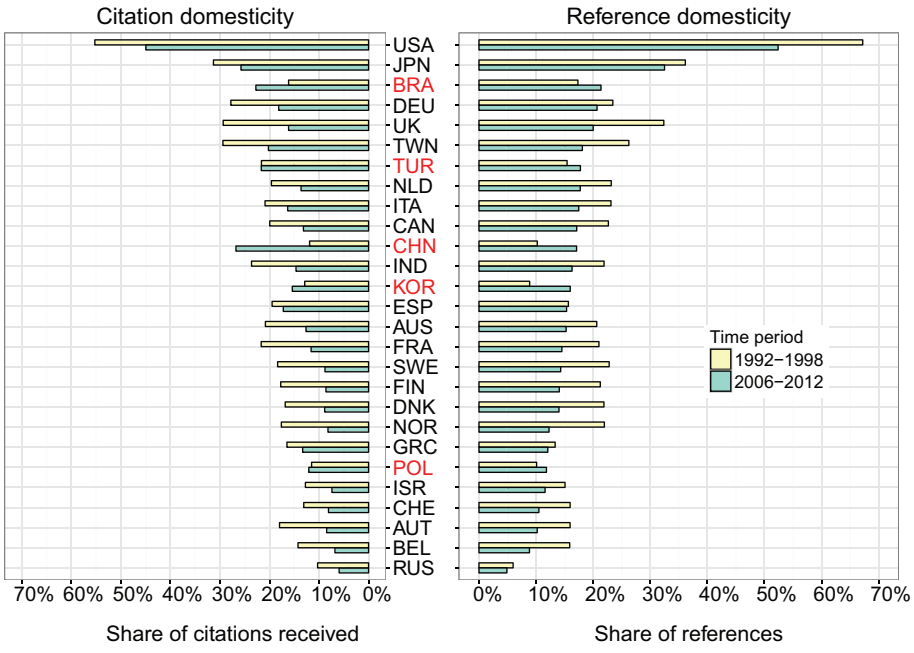

Figure 6 Citation and reference domesticity. Citation domesticity (left) represents the share of citations to the cardiovascular dataset coming from the same country as the country of the cited publications in the dataset; reference domesticity (right) represents the share of references in the publications of the cardiovascular dataset that have authors from the same country. The country codes highlighted in red indicate an increase in domesticity between 1992–1998 and 2006–2012. (Data sourced from Thomson Reuters Web of Science Core Collection.)

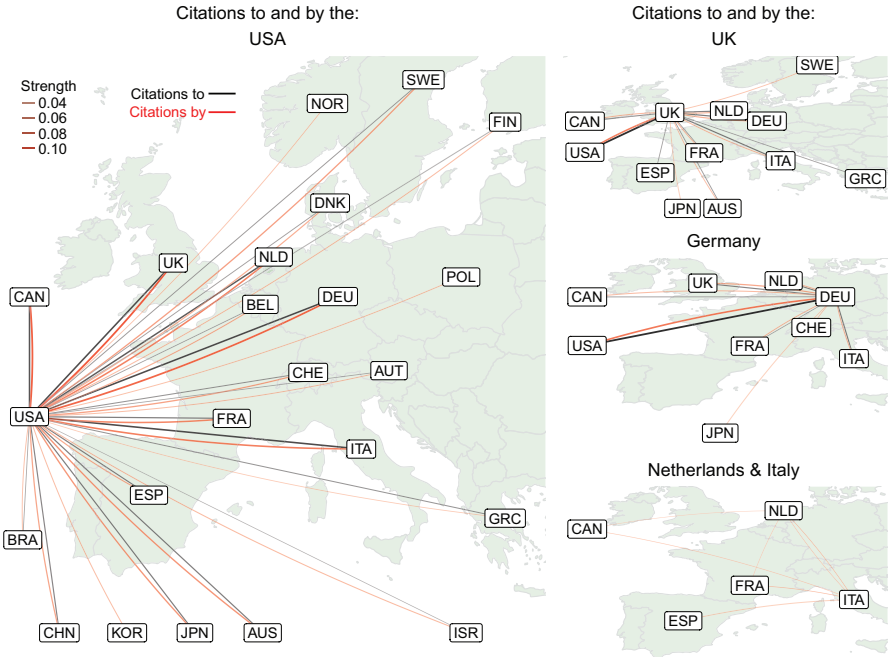

Figure 7 Flow of citations between countries 2006–2012. The increased width and colour of the line represent stronger citation links. Only strong citation links are presented where the strength of collaboration was at least 0.03 in one time period between country pairs. The left panel presents citations to (straight black line) and by (curved red line) the USA, whereas the panel on the right shows the data for the UK, Germany and the Netherlands and Italy combined. (Data sourced from Thomson Reuters Web of Science Core Collection.)

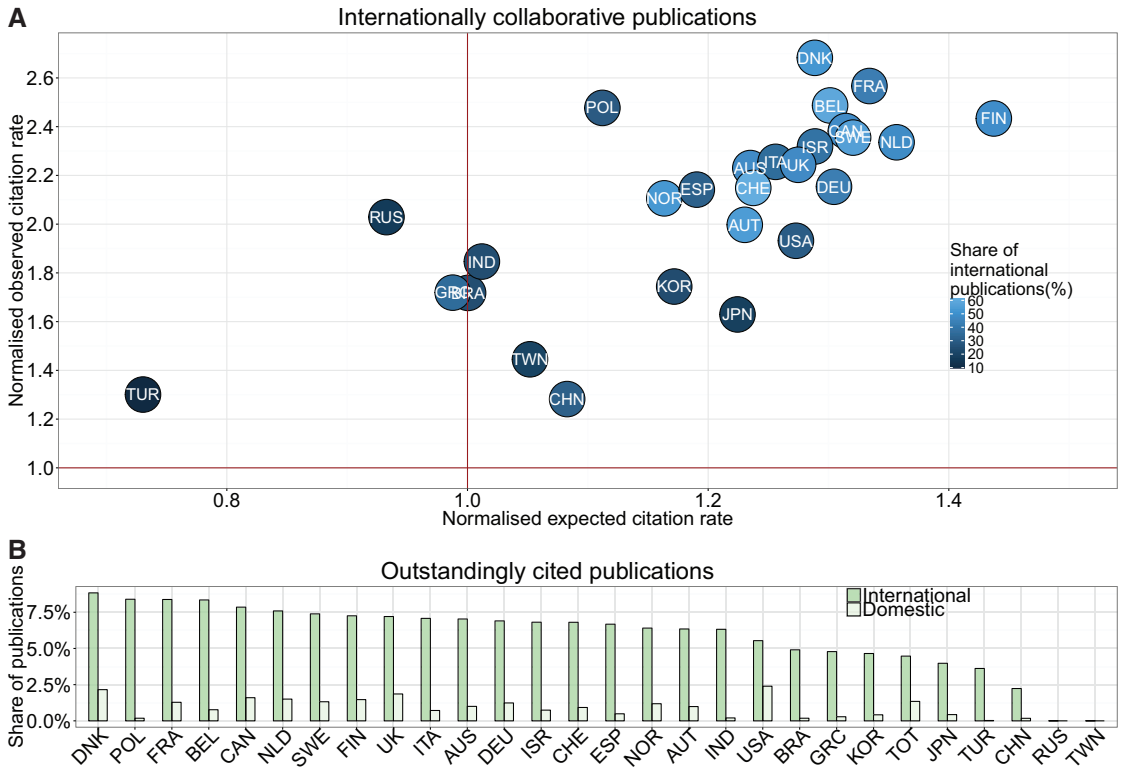

Figure 8 Impact of collaboration by country 2006–2012. (*A*) Definitions as per *Figure 2*; data for internationally collaborative publications. The share of international publications increases as the colour of the point changes from black to light blue. (*B*) For each country, the share of outstandingly cited international publications in their total international publications is compared with the share of outstandingly cited domestic publications in their total domestic publications. (Data sourced from Thomson Reuters Web of Science Core Collection.)

countries overall are in line with present data. Yu *et al.*,[22] took a network analysis approach to studying scientific collaboration in coronary disease. They found a lower level of internationally collaborative research up to only 16% in 2010 and concluded that the USA ranked the highest in terms of international collaboration, with France and Great Britain also playing important roles within a core network between western countries. These differences may be due to specific bibliometric strategies or reflect the particular situation of research in CAD.

Methodological limitations to the present study are discussed in the Supplementary material online, *File S1*.

Research and policy perspectives

The growing interest in using science and technology indicators, including bibliometric indicators, is fuelled in part by the substantial growth in and availability of research and data, and also by the scientific goal to provide objective data to inform decision-making. Although this study has shown increases in cardiovascular research activity, communication, and collaboration, there are wide variations between countries, which are important to understand when setting research strategies and expectations. The present study contributes objective evidence to inform research policy and help to comprehensively review and place cardiovascular research within the global landscape.

The data suggest there is an overall association between international collaboration and impact, by publishing in higher impact journals and obtaining higher shares of citations. These publications are not only clinical trials; analysis of a sample indicates that clinical trials account for only one quarter of the highest impact collaborative publications. A preliminary broad topic analysis of the 2010–2012 data set shows that collaborative work comes from all types of research, i.e. population/public health/risk factor research; mechanistic and exploratory (basic and clinical) research; clinical and applied/interventional research, as detailed and presented in the Supplementary material online, *Figure S1D*. Successful collaborations generate opportunities to build on each partner's strengths and to share resources leading to higher impact research. However, bibliometric methods provide answers to the 'how much' and 'what' questions but not to the 'how' or 'why' questions. Further research is needed to explain why or how these changes occurred within and between countries. Being able to match funding to publications would help to answer some of these questions, however comprehensive data are often not available and/or sufficiently reliable. National or charitable funding bodies are well placed to study their grantees output,[23] however few supra-national regions have a broader view of allocated funding and if so only for a short-term perspective such as from projects like CardioScape.[7] The available data show high levels of national funding

for cardiovascular research in the UK, Germany, and France, as is the case for biomedical research overall.[10] The EU framework programs may underlie the growth of collaborative publication output within Europe.

Future research is also needed to better describe and refine cardiovascular research topics; as a very broad field with many interconnections with other research fields, current journal based classifications are insufficient to fully characterize the breadth and depth of cardiovascular research. Using document network and topic mapping techniques, a study is underway to investigate more specific topics, e.g. public health/risk factors, miRs, and personalised medicine.[24] The interaction between exploratory research and clinical research, and the role of the changing publication landscape will be part of this study. This further investigation of the topics may also inform on emerging fields of research over time and on the impact of collaborations on topics.

Presently we were not able to assess the quality of the research or its 'societal impact' in leading to innovative cardiovascular interventions that improve health. For example, the addition of data on patents and burden of disease could potentially allow a macro-level evaluation of societal impact of cardiovascular research. Currently the indicators of innovation such as the low growth of new molecular entities (NMEs) and biologicals in the USA[25] compared with the substantial growth in research would support the idea that the 'translational gap' is pronounced. For this, however, further analysis is needed of public–private partnerships and the biotech evolution in the field.

Conclusions

The present study has mapped the growing participation across the world in cardiovascular research and the increasing international cross-border collaboration. However, growth and impact show wide variability between countries. Cross-border collaboration is associated with greater impact. Future research will refine the evolution within the field regarding topics studied and relation to journals and publication forums.

Supplementary material

Supplementary material is available at *European Heart Journal* online.

Acknowledgements

Thank you to Mehmet Ali Abdulhayoglu for cleaning and processing the data for the preliminary topic network and cluster analysis.

Funding

Funding for open access charge: supported by internal KU Leuven funds to Karin Sipido.

Conflict of interest: none declared.

References

1. Nichols M, Townsend N, Scarborough P, Rayner M. Cardiovascular disease in Europe 2014: epidemiological update. *Eur Heart J* 2014;**35**:2950–2959.
2. Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, Dai S, Ford ES, Fox CS, Franco S, Fullerton HJ, Gillespie C, Hailpern SM, Heit JA, Howard VJ, Huffman MD, Judd SE, Kissela BM, Kittner SJ, Lackland DT, Lichtman JH, Lisabeth LD, Mackey RH, Magid DJ, Marcus GM, Marelli A, Matchar DB, McGuire DK, Mohler ER, Moy CS, Mussolino ME, Neumar RW, Nichol G, Pandey DK, Paynter NP, Reeves MJ, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Wong ND, Woo D, Turner MB on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2014 update: a report from the American Heart Association. *Circulation* 2014;**129**:e28–e292.
3. WHO. *Health in 2015: from MDGs, Millennium Development Goals to SDGs, Sustainable Development Goals*. Geneva, Switzerland: World Health Organization; 2015. p204.
4. HORIZON 2020—European Commission.https://ec.europa.eu/programmes/horizon2020/ (28 April 2016).
5. New funding opportunities through the Recovery Act | NIH Extramural Nexus. https://nexus.od.nih.gov/all/2009/06/01/new-funding-opportunities-through-the-recovery-act/ (28 April 2016).
6. Fondation Leducq. https://www.fondationleducq.org/ (28 April 2016).
7. European Society of Cardiology. *CardioScape: A Survey of the European Cardiovascular Research Landscape*. Brussels, Belgium: European Society of Cardiology; 2014. p52.
8. Moses H, Matheson DHM, Cairns-Smith S, George BP, Palisch C, Dorsey ER. The anatomy of medical research: US and international comparisons. *JAMA* 2015;**313**:174.
9. Chakma J, Sun GH, Steinberg JD, Sammut SM, Jagsi R. Asia's ascent—global trends in biomedical R&D expenditures. *N Engl J Med* 2014;**370**:3–6.
10. Deloitte Health Economics Group. *Investing in European Health R&D: A Pathway to Sustained Innovation and Stronger Economies*. Belgium: Deloitte; 2015. p36.
11. Glänzel W. *Bibliometrics as a Research Field: A Course on Theory and Application of Bibliometric Methods*. Leuven: KU Leuven; 2014.
12. Glänzel W, Thijs B, Debackere K. The application of citation-based performance classes to the disciplinary and multidisciplinary assessment in national comparison and institutional research assessment. *Scientometrics* 2014;**101**:939–952.
13. Glänzel W, Schubert A. Double effort = Double impact? A critical view at international co-authorship in chemistry. *Scientometrics* 2001;**50**:199–214.
14. Glänzel W, Schubert A. Domesticity and internationality in co-authorship, references and citations. *Scientometrics* 2005;**65**:323–342.
15. Zhang L, Janssens F, Liang L, Glänzel W. Journal cross-citation analysis for validation and improvement of journal-based subject classification in bibliometric research. *Scientometrics* 2010;**82**:687–706.
16. RStudio Team. *RStudio: Integrated Development Environment for R*. Boston, MA: RStudio, Inc.; 2015.
17. Thomson Reuters. *The Research & Innovation Performance of the G20 and its Impact on Decisions made by the World's Most Influential Economic Leaders*. USA: Thomson Reuters; 2014. 86.
18. Gao F, Sun RJ, Ji Y, Yang BF. Cardiovascular research is thriving in China: cardiovascular research in China. *Br J Pharmacol* 2015;**172**:5430–5434.
19. Bolaños-Pizarro M, Thijs B, Glänzel W. Cardiovascular research in Spain. A comparative scientometric study. *Scientometrics* 2010;**85**:509–526.
20. Huffman MD, Baldridge A, Bloomfield GS, Colantonio LD, Prabhakaran P, Ajay VS, Suh S, Lewison G, Prabhakaran D. Global cardiovascular research output, citations, and collaborations: a time-trend, bibliometric analysis (1999–2008). *PLoS One* 2013;**8**:e83440.
21. Baldridge AS, Huffman MD, Bloomfield GS, Prabhakaran D. Footprint and imprint: an ecologic time-trend analysis of cardiovascular publications in general and specialty journals. *Glob Heart* 2014;**9**:263.e2–269.e2.
22. Yu Q, Shao H, He P, Duan Z. World scientific collaboration in coronary heart disease research. *Int J Cardiol* 2013;**167**:631–639.
23. Danthi NS, Wu CO, DiMichele DM, Hoots WK, Lauer MS. Citation impact of NHLBI R01 grants funded through the American Recovery and Reinvestment Act as compared to R01 grants funded through a standard payline. *Circ Res* 2015;**116**:784–788.
24. Kirchhof P, Sipido KR, Cowie MR, Eschenhagen T, Fox KAA, Katus H, Schroeder S, Schunkert H, Priori S, ESC CRT R&D and European Affairs Work Shop on Personalized Medicine, Alonso A, Chezaubernard C, Doevendans P, Eschenhagen T, Fox K, Katus H, Khder Y, Kirchhof P, Kramer F, Kristensen S, Maitland-Van der Zee A-H, Oertelt-Prigione S, Pinto F, Pocock S, Priori SG, Sartorius A, Schott D, Schroeder S, Schunkert H, Schwab M, Sipido K, Svensson A, Swedberg K, Wallentin L, Weimers M, Herttuala SY. The continuum of personalized cardiovascular medicine: a position paper of the European Society of Cardiology. *Eur Heart J* 2014;**35**:3250–3257.
25. CenterWatch. FDA approved drugs in cardiology/vascular diseases. https://www.centerwatch.com/drug-information/fda-approved-drugs/therapeutic-area/1/cardiology-vascular-diseases (7 December 2015).